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The role of optic nerve sheath diameter measurement in the diagnosis of brain death

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Abstract. – OBJECTIVE: The aim of this study is to evaluate the correlation between optic nerve sheath diameter (ONSD) measured using computed tomography (CT), and ONSD measured using bedside ultrasonography (USG) in the diagnosis of brain death.

PATIENTS AND METHODS: A total of 21 brain-dead patients were included in the study. The ONSD values of these patients were measured using both USG and CT before and after brain death, and the relationship between these measurements was evaluated.

RESULTS: There was a high level of correlation between the right-left eye ONSD measurements conducted before brain death using USG and CT, respectively (p=0.000, p=0.001). There was a high level of correlation between the right-left eye ONSD measurements conducted after brain death using USG and CT, respectively (p=0.000, p=0.00). Pre-brain death ONSD mean values of both left and right eyes, measured using USG and CT, were found to be statistically significantly lower than the mean values of post-brain death measurements.

CONCLUSIONS: In conclusion, a statistically significant difference was found between the optic nerve sheath diameter values measured before and after brain death using USG and CT. At the same time, it was determined that the values of the optic nerve sheath diameter measured using both CT and USG were correlated.

Key Words:
Brain death, Optic nerve sheath diameter, Ultrasonography, Computed tomography.

Introduction

Brain death is the loss of brain and brainstem functions and is characterized by coma, absence of spontaneous breathing, and loss of all brainstem reflexes. These reflexes are corneal reflex, oculocephalic and oculovestibular reflex, pupillary light reflex, oropharyngeal reflex, and respiratory reflex[1]. Brain death is the condition of cerebral blood flow cessation and stopping of cerebral perfusion because of cerebral edema and increased intracranial pressure (ICP)[2]. Imaging methods such as angiography, computed tomography angiography (CTA), and magnetic resonance angiography (MRA) are the main methods used to show that blood flow has ceased[3].

The optic nerve sheath is covered by the subarachnoid membrane and continues with the meninges of the central nervous system. Cerebrospinal fluid is localized in the subarachnoid space, the pressure around the optic nerve increases because of the limitation of the compliance of the intracranial component and the increase in ICP, and the dural sheath expands, causing an increase in optic nerve sheath diameter (ONSD)[4].

Some clinical studies[5,6] have shown that ONSD measured with ultrasonographic methods has high specificity and is also correlated with intracranial pressure measurements taken with invasive methods. Our aim in this study is to evaluate the correlation between ONSD measured with computed tomography and ONSD measured with bedside ultrasonography in the diagnosis of brain death.

Patients and Methods

Patient Selection

This study was designed as a retrospective study. A total of 120 patients, monitored in the intensive care unit of Burdur Public Hospital between 2018 and 2022, were included in our study. Patients with subarachnoid hemorrhage, traumatic brain injury, intracerebral hemorrhage, ischemic stroke, post-cardiac arrest (patients with

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hypoxic encephalopathy), and those who stayed in the intensive care unit for at least 24 hours due to coma (not opening their eyes, not following commands, saying incomprehensible words in response to painful stimuli), being on a mechanical ventilator, and having a cranial CT scan at the time of hospitalization were included in our study[7]. Patients who were not in a coma, who had facial trauma and skull base fracture that prevented the evaluation of brainstem reflexes, and who had optic nerve trauma, or a condition that prevented the evaluation of the optic nerve, were not included in the study.

Optic Nerve Sheath Diameter Measurement

Right-left eye ONSD measurements of the patients included in the study were taken with bedside ultrasonography immediately after admission to the intensive care unit. Right-left eye ONSD measurements of the patients were also taken through the brain CT scans taken at the time of hospitalization. This data was recorded regularly. When the patients were clinically diagnosed to be brain dead, and it was decided to carry out CTA as a supportive test, USG measurements were first taken, and then CTA was performed immediately. An example of CT and USG measurement images are provided in Figure 1 and Figure 2, respectively.

A pre-scan was carried out without contrast during the CTA scan. Brain death diagnosis was confirmed in 24 of 120 patients included in our study. Three of our patients diagnosed as brain dead were excluded from the study due to optic nerve damage and severe facial trauma. The study was completed with a total of 21 patients. A flow chart of the study is presented in Figure 3.

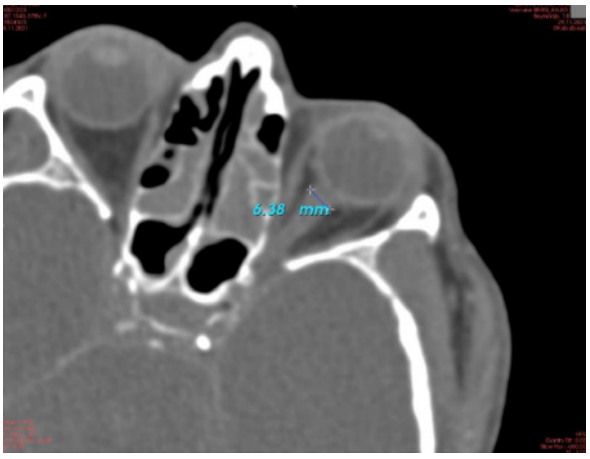

Figure 1. Brain computed tomography scan image of the eye globe of a representative patient with brain death, showing an enlarged ONSD (6.38 mm).

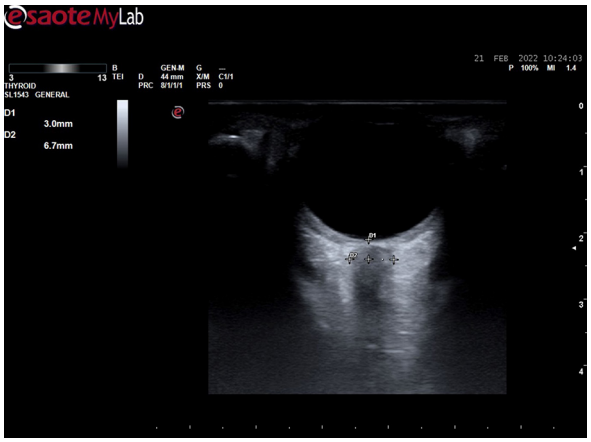

Figure 2. Two-dimensional (B-mode) image of the eye globe of a representative patient with brain death, showing an enlarged ONSD (6.7 mm).

The optic nerve sheath diameter measurement was taken by an intensive care specialist experienced in ultrasonography. The same person took all the measurements to avoid individual differences affecting measurements. Measurements were taken in the supine position using the 12-MHz linear probe of the bedside USG device (EsaoteMyLab Seven, Genova, Italy). With both eyes closed, the USG probe was placed vertically over the eye, and the USG rays were directed toward the posterior of the optic disc and optic nerve. The measurements were taken at a distance of 3 mm from the eyeball[8]. A total of two measurements were taken for each eye, vertically and transversely. The mean value of a total of eight measurements was calculated. This technique has been reported in studies[9] to minimize operator-induced variability.

Measurements of ONSD through CT were taken with a Siemens Emotion 16 (2010) 78488, Somaris/5 syngo 2014 A (Forchheim, Siemens-str, Germany) device, and images were obtained from 3 mm sections. The ONSD measurement in tomographic data was taken by an experienced radiology specialist by magnifying the images 2 times, and the results were confirmed by an experienced radiologist. The images were obtained from the brain window, which shows the full ONSD in maximum detail. The ONSD was measured 3 mm behind the globe, perpendicular to the linear axis of the nerve during the CT[10].

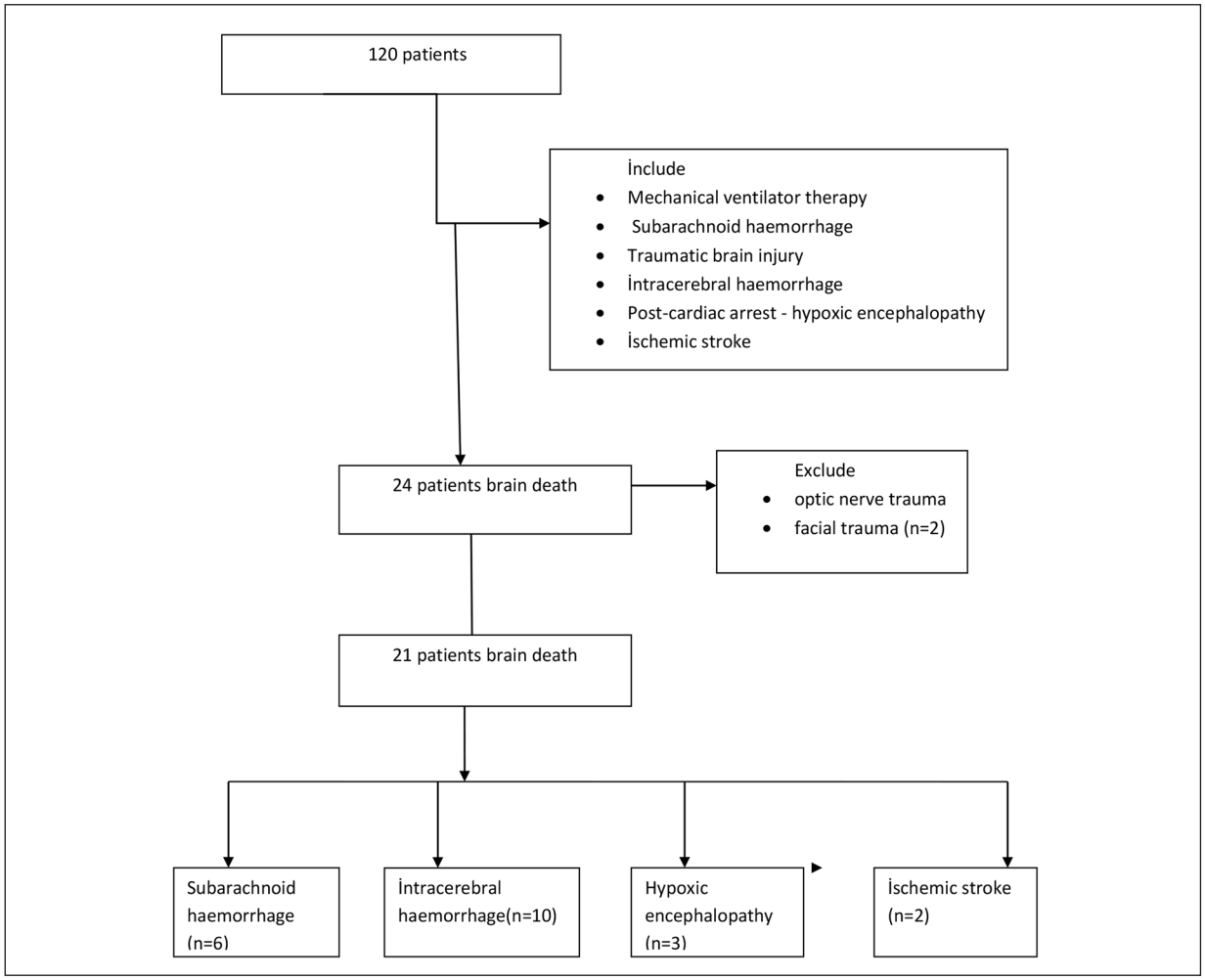

Figure 3. Flowchart of the study.

Statistical Analysis

The data was analyzed using Statistical Package for the Social Sciences (SPSS) 22 (IBM Corp., Armonk, NY, USA). Kolmogorov-Smirnov and Shapiro-Wilk normality tests were used to check the suitability of continuous variables to the normal distribution, which is a necessary assumption for the application of parametric tests. The Kolmogorov-Smirnov test of normality showed that none of the continuous variables included in the test demonstrated a statistically significant difference from the normal distribution (p>0.05). The results of the Shapiro-Wilk normality test, which has a higher power to reject the normality null hypothesis correctly (without Type I error) in cases where the sample size is small, the null hypothesis that the values obtained from the variables differ from the normal distribution was rejected at a confidence interval of 0.95 (p>0.05).

To determine the level of the relationship between the continuous variables included in the study, the Pearson Correlation coefficient was calculated and reported. Furthermore, analysis of the study data included the dependent (paired) sample t-test, used to test the null hypothesis that the values obtained before and after brain death from the related variables showed statistically significant differences.

Results

A total of 21 brain-dead patients were included in the study. Thirteen (61.9%) of the patients were male, and the mean age of the participants was 60.05±19.09 years. In patients with brain death, the most common cause was subarachnoid hemorrhage due to hypertension (47.6%).

In 21 brain-dead patients, there was a high level of correlation between the right eye ONSD measured using USG and the right eye ONSD measured using CT before brain death (r=0.694, *p*=0.000). There was a high level of correlation between the left eye ONSD measured using USG, and the left eye ONSD measured using CT before brain death (r=0.656, *p*=0.001).

There was a high level of correlation between the right eye ONSD measured using USG and the right eye ONSD measured using CT after brain death *(*r=0.818, *p*=0.000). There was a high level of correlation between the left eye ONSD measured using USG, and the left eye ONSD measured using CT after brain death (r=0.745, *p*=0.00). The linear relationship findings between the variables are presented in Table I.

The mean value of left eye optic nerve diameter measured before brain death (Mean=4.339, Standard Deviation=0.285) was found to be significantly lower than the mean value of left eye optic nerve diameter measured after brain death (Mean=5.952, Standard Deviation=0.464) (*t*=-16.324, *p*=0.000). Similarly, the mean value of right eye optic nerve diameter measured using USG before brain death (Mean=4.443, Standard Deviation=0.260) was found to be significantly lower than the mean value of right eye optic nerve diameter measured using USG after brain death (Mean=6.110, Standard Deviation=0.532) (*t*=-16.011, *p*=0.000). Furthermore, the mean values of both left and right eye optic nerve diameter measured using CT before brain death (Mean=4.460, Standard Deviation=0.321; Mean=4.498, Standard Deviation=0.284, respectively) were found to be significantly lower than the mean values of measurements taken after brain death (Mean=5.911, Standard Deviation=0.414; Mean=5.986, Standard Deviation=0.526, respectively) (*t*=-14.568, *p*=0.000; *t*=-14.505, *p*=0.000, respectively). Relevant findings are also presented in Table II.

Discussion

This study, which is unique in the literature, evaluated the optic nerve sheath diameters of patients before and after brain death using both USG and CT. It has shown that there was a statistically significant difference between the measurements of ONSD in the patients taken both using CT and USG before and after brain death. It has also been determined that there was a significant correlation between the ONSD values before and after brain death taken using CT and USG.

The most important pathophysiological mechanism of brain death is the complete cessation of intracranial blood flow due to increased intracranial pressure. High intracranial pressure and low cerebral perfusion pressure (CPP) are strong predictors of poor prognosis and high mortality[11]. There are signs of cerebral herniation in brain death. Furthermore, defined threshold values for ICP and CPP, important components of cerebral blood flow, are also lost. The condition of brain death is the cessation of cerebral blood flow[12,13].

Table I. Pearson's correlation coefficients.

	BBD CT		ABD CT		BBD USG		ABD USG	
	Left	Right	Left	Right	Left	Right	Left	Right
BBD USG								
Left	0.656**	0.672**	0.245	0.160	1	0.672**	0.347	0.065
Right	0.516*	0.694**	0.407	0.420	0.672**	1	0.439*	0.446*
ABD USG								
Left	0.344	0.257	0.805**	0.702**	0.347	0.439*	1	0.789**
Right	0.069	0.379	0.745**	0.818**	0.065	0.466*	0.789**	1
BBD CT								
Left	1	0.458*	0.247	0.055	0.656**	0.516*	0.344	0.069
Right	0.458*	1	0.409	0.409	0.160	0.694**	0.257	0.379
ABD CT								
Left	0.247	0.409	1	0.904**	0.245	0.407	0.805**	0.745**
Right	0.055	0.409	0.904**	1	0.160	0.420	0.702**	0.818**

BBD: Before Brain Death; ABD: After Brain Death; CT: Computed Tomography; USG: Ultrasonography. **The correlation is significant at the 0.01 level (2-tailed). *The correlation is significant at the 0.05 level (2-tailed).

Table II. Dependent (Paired) sample *t*-test findings.

	Brain death	Mean	Standard deviation	*t*	df	Sig. (2-tailed)
US Left	Before	4.3390	.28534	-16.324	20	0.000
	After	5.9524	.46435			
US Right	Before	4.4438	.26020	-16.011	20	0.000
	After	6.1095	.53189			
CT Left	Before	4.4600	.32067	-14.568	20	0.000
	After	5.9110	.41353			
CT Right	Before	4.4986	.28396	-14.055	20	0.000
	After	5.9857	.52608			

CT: Computed Tomography; USG: Ultrasonography.

Studies[14,15] have been carried out on the ultrasonographic measurement of optic nerve sheath diameter (ONSD), which is a non-invasive method for rapid detection of increasing ICP. In their study evaluating ONSD with USG, Topcuoglu et al[16] reported significantly higher values of ONSD in the brain-dead group compared to the group who were not brain-dead. In another study[17], the ONSD measured using USG in brain-dead patients was reported to be significantly wider than in healthy individuals, while the ONSD of brain-dead patients was significantly wider than the group in a deep coma.

There is no other study in the literature comparisoning ONSD measurement before and after brain death. This current study found a statistically significant difference in ONSD values measured using USG before and after brain death (p=0.000).

Sekhon et al[18] report that there was a strong correlation between the increase in ICP and the ONSD measured using CT simultaneously. They also report that the ONSD measurement has a superior predictive value compared to the classical findings of ICP increase in CT. Jenjitranant et al[19] also report a significant relationship between ICP increase and ONSD enlargement in patients with traumatic brain injury. In the reviewed literature, no studies were found in which ONSD values were measured with CT in patients diagnosed as brain dead. In this current study, a statistically significant difference was found in the ONSD values measured using CT before and after the diagnosis of brain death (p=0.000). Since brain death is a clinical condition with an increase in ICP, the increase in the ONSD value is not unexpected. Therefore, these findings are in line with studies in the literature showing ICP increase and ONSD enlargement.

Kim et al[20] found that patients with high ICP had an increase in ONSD measured using USG and CT and reported that the ONSD measured using USG and CT almost simultaneously (within a 30-minute time frame) showed a high number of similarities. Munawar et al[21], in their study evaluating patients with increased ICP due to traumatic brain injury, took the cut-off value as >0.58 cm in ONSD and report a consistency between CT and USG. In this current study, there was a high level of a positive linear relationship between CT and USG in ONSD values before brain death. At the same time, a high positive linear relationship was found between the measurements taken using CT and USG in patients who were brain dead.

Limitations

There are some limitations to this study. Firstly, the data was obtained retrospectively. The second limitation is that it included a small study sample since it was difficult to gain access to brain-dead patient groups and conduct studies with them. The third limitation is that the measurements were taken by two physicians. No evaluation was requested from a third observer.

Conclusions

In conclusion, this is the first original study in which ONSD values were measured before and after brain death, both using USG and CT, and a statistically significant difference was found between these measurements. It was determined that the optic nerve sheath diameter values measured using both CT and USG were correlated. The importance of brain death diagnosis is increasing due to the increasing need for organ transplants both nationally and globally. A bed-

side USG can be a good guide to avoid various difficulties and delays during diagnosis. There is a need for further comprehensive studies to be conducted in order for USG to be recommended for routine use in the diagnosis of brain death.

Conflict of Interest
The Authors declare that they have no conflict of interests.

Ethics Approval
Approval of the study was obtained with the decision of Afyonkarahisar University of Health Sciences Ethics Committee meeting with number 2022/418.

Informed Consent
Since this is a retrospective study, the informed consent was waived.

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Data Availability
The data supporting this article is available from the corresponding author on reasonable request.

Authors' Contribution
The study design; KYG, SO, SBO data collection; KYG, SBO and data analysis under the supervision of KYG.; KYG, SO. data interpretation and manuscript writing; KYG, SO.; KYG, SO. and SBO. Review and editing; KYG, SO. and SBO supervision and project administration. All authors approved the final version of the manuscript.

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